Vascularized Bone Grafting for the Treatment of Capitate Avascular Necrosis

Jorge I. Quintero, MD[1] Maria C. Herrand, MD[1] Rodrigo Moreno, MD[1]

[1] Christine M. Kleinert Institute for Hand and Microsurgery, Louisville, Kentucky

J Wrist Surg 2022;11:181–184.

Address for correspondence Jorge I. Quintero, MD, Christine M. Kleinert Institute for Hand and Microsurgery, 225 Abraham Flexner Way, Suite 850, Louisville, KY 40202 (e-mail: jorgekin82@hotmail.com).

Abstract

Avascular necrosis (AVN) of the capitate bone is a rare condition and it can be related to major trauma or idiopathy. Different treatments are available including soft tissue interposition and intercarpal arthrodesis including lunocapitate, scaphocapitate, four corner, and carpometacarpal fusions. Other surgical options are resection of the proximal pole and revascularization procedures. The main purpose of this article is to present two cases of AVN of the capitate treated with a revascularization procedure using the 4th–5th extensor compartment artery (4th–5th ECA). Two female patients with capitate AVN are reported with an average age of 30.5 years. Both cases were classified as type-I according to Milliez classification. The major complaint in each case was wrist pain that increased during activity. In both cases there was no history of trauma, smoking, diabetes, or hematologic diseases. Both patients had a diminished range of motion, grip, and strength. The definitive diagnosis was made with magnetic resonance imaging. Both patients underwent treatment revascularization of the capitate using a vascularized bone graft based on the 4th–5th ECA. At average follow-up of 12 months, each patient had improved with regards to pain and had increased grip strength. The literature does not describe a specific algorithm treatment for capitate AVN. We recommend revascularization of the capitate using the 4th–5th ECA in type-I Milliez classification in young patients without signs of carpal collapse.

Keywords
- avascular necrosis
- capitate
- bone graft
- carpal height
- vascularized

Primary avascular necrosis (AVN) of the capitate bone is a rare condition that generally arises between the second and third decade of life. The etiology is not completely understood. Typical presentation is a patient between 20 and 30 years of age complaining of disabling wrist pain with limited range of motion and mild-to-moderate swelling.[1–3]

Different surgical techniques have been reported depending mostly on the status of the proximal pole of the capitate cartilage and fragmentation. Treatment of this condition can be divided on anatomic preserving techniques of the capitate (revascularization procedures)[1,4,5] and salvage procedures (intercarpal arthrodesis, resection of the proximal pole with tendon interposition, and replacement of the proximal pole with prosthesis of the capitate).[2,6–8] Revascularization techniques include pedicled vascularized bone grafts from the second metacarpal and from the distal radius. Disadvantages of the metacarpal graft are the limited size that can be harvested and the risk of fracture. The medial femoral condyle graft has been used to treat this condition but requires a secondary site for harvesting, and microsurgical technique is required.

The purpose of the this work is to report two cases of AVN of the capitate treated with a revascularization procedure using a pedicled vascularized one graft from the dorsal aspect of the radius using the 4th–5th extensor compartment artery (ECA).

received
January 1, 2021
accepted after revision
February 9, 2021
published online
March 24, 2021

DOI https://doi.org/10.1055/s-0041-1726410.
ISSN 2163-3916.

Cases

A 29-year-old female, right hand-dominant, presented with left dorsal wrist pain for 3 months, denying any major trauma. Pain was aggravated with wrist motion reported in some occasions to be 10/10 according to the Visual Analogue Scale (VAS). Past medical history was positive for smoking and negative for any chronic medications.

The patient was evaluated initially by her primary care physician and treated with nonsteroidal inflammatory drugs without improvement. Our first evaluation showed diffuse tenderness at the dorsal aspect of the wrist with flexion of 35 degrees and extension of 40 degrees. Radial deviation was 20 degrees and ulnar deviation was 30 degrees. Pronation and supination of the forearm were the best 80/80 degrees. Grip strength of the left hand was 30 pounds compared with 75 pounds on the right. Initial X-rays showed slight radiolucency at the body of the capitate with minimal carpal height loss of 1.48 compared with 1.52 (according to Nattrass method)[9] of the unaffected wrist. Both the scaphocapitate and lunocapitate joints under T1-weighed magnetic resonance imaging (MRI) showed a diffuse low signal intensity at the body of the capitate bone compatible with osteonecrosis. This led to a diagnosis of left capitate AVN.

The second case was a 32-year-old female, right hand-dominant, nonsmoker, presented with a pain score of 6 out of a possible 10 at the dorsal ulnar aspect of the right wrist. She presented worse with active motion and had a similar episode 1-year prior that resolved. No trauma was reported. Her first evaluation in our clinic showed no swelling and positive tenderness at the midcarpal joint and the ulnocarpal area. Range of motion of the wrist was flexion of 80 degrees and extension of 70 degrees. Radial deviation was 20 degrees and ulnar deviation was 35 degrees. Pronation and supination were normal and grip strength of the right hand was 20 pounds compared with 45 pounds on the left hand. Initial right wrist X-ray showed a right capitate proximal radiolucency 3×3 mm near the articular surface of the lunocapitate joint and a carpal height of 1.54. T1-weighted MRI showed AVN of the capitate with low-intensity signal collapse of the proximal articular surface and moderate diffuse chondromalacia of the lunocapitate joint. A diagnosis of right capitate AVN type Ia of the capitate according to Milliez[10] classification was made.

Methods

Both patients were treated surgically with a revascularization procedure with a pedicled bone graft from the 4th and 5th ECA. A dorsal longitudinal incision over the wrist of approximately 8 cm was performed. The subcutaneous tissue was dissected to expose the extensor retinaculum. The 4th extensor compartment was opened in a step-cut fashion, and the tendons were retracted ulnarly to expose the dorsal aspect of the radius and the capsule of the wrist. The midcarpal joint is opened in a transverse fashion, and the cartilage of the capitate and lunate was evaluated, observing no fragmentation in both cases (in the second case, the cartilage was soft in half of the articular surface without fragmentation).

Next, a dorsal cortical window of the capitate was created with the use of a small oscillating saw and osteotomes. Necrotic bone from the body of the capitate was debrided and removed with a burr and curettes. Defect was measured, and attention was directed to the dorsal aspect of the radius. The arteries over the 4th and 5th extensor compartments were identified, as well as the proximal connection between both of them. The posterior division of the anterior interosseous artery was ligated proximal to the connection between the 4th and 5th ECA. Graft was harvested from the dorsal aspect of the radius proximal to the radiocarpal joint based on the 4th ECA using a small oscillating saw and small osteotomes. The pedicle of the 4th and 5th ECA was elevated from the dorsal aspect of the radius all the way to the radiocarpal joint so it can be rotated to the capitate. The first case's graft measured $10 \times 6 \times 8$ mm and the second case's graft measured $8 \times 5 \times 8$ mm. Both grafts were carved to press fit inside the capitate defect, and no fixation was necessary in any of the cases. The surgical technique was performed according with Butterworth and Moran.[11]

A distal radius cancellous bone graft was packed just distal to the articular surface of the capitate to fill completely the defect. The tourniquet was deflated and visual confirmation of bleeding of the vascularized bone graft was performed in both cases. The capsule was approximated with interrupted nonabsorbable sutures. Finally, the 4th extensor compartment was repaired. A volar wrist plaster splint was placed for 2 weeks and then a short arm cast was placed for 4 more weeks. No external fixator was used in any of the cases. The wrist was immobilized for 6 weeks, and then physical therapy was started.

Follow-Up

The first case at 1-year follow-up had no complaints, VAS was 0/10. The first case was on regular duty with no restrictions. Extension of the wrist was 60 degrees, flexion 50 degrees, radial deviation 20 degrees, and ulnar deviation 30 degrees. Pronation and supination were unchanged from initial evaluation before surgery. Final postoperative X-rays showed a carpal height of 1.42 (►**Fig. 1**).

The second case at 20 months after surgery reported pain 4/10 mostly when the wrist was loaded in dorsiflexion. Active range of motion was 60 degrees of extension, flexion 65 degrees, radial deviation 20 degrees, and ulnar deviation 35 degrees. Grip strength improved to 60 pounds. X-ray revealed no progression of the collapse, and carpal height remained 1.51. DASH (disabilities of the arm, shoulder, and hand) score was 29.2. At this time MRI shows minimal progression to midcarpal, and the hypothesis is that even with vascular bone graft the necrosis is already established leading to arthritis (►**Fig. 2**; ►**Tables 1** and **2**).

Discussion

Etiology of capitate AVN is not completely well understood. It has been associated with venous thrombosis, increased bone pressure, reduced retrograde blood flow, or hematologic

Fig. 1 Patient number 1: initial MRI, initial X-ray, X-ray 12 months follow-up. MRI, magnetic resonance imaging.

Fig. 2 Patient number 2: initial MRI, initial X-ray, X-ray, and MRI 15 months follow-up. MRI, magnetic resonance imaging.

conditions such as hypofibrinolysis and thrombophilia.[4] The pattern of the vascularity of the capitate is important to take into consideration in the pathophysiology of this condition.[10,12] Group 1: vessels entering the capitate from the distal palmar and dorsal side running retrograde to the proximal pole. Group 2: vessels entering as group 1 but the palmar branch is the only one running retrograde to the proximal pole. Group 3: only one vessel entering from the palmar side. Capitate vascularity is mainly from the volar aspect with retrograde flow.[13,14] In those cases where the blood supply is restricted to a volar blood supply, it is possible that these cases are prone to have AVN.

This condition has been reported in younger adults with repetitive trauma, dorsal carpal instability, corticosteroid use, gout, and other diseases like systemic lupus erythematosus and scleroderma.[2,15] Initial radiologic findings can show radiolucency at the proximal pole of the capitate or can be normal.[12] Capitate AVN is a challenging diagnosis, and the cardinal symptom is dorsal wrist pain with or without prior trauma. The diagnosis is typically based on X-rays and confirmed with MRI.[10]

Treatment options will depend on the integrity of the capitate and the proximal articular cartilage status. If the carpal height is maintained and cartilage is preserved,

Table 1 Demographic, pain, range of motion, carpal height

Patient	Gender	Age	Wrist	Main symptom	Smoker	Initial wrist flexion	Initial wrist extension	Initial VAS	Initial grip jamar (pounds)	Initial carpal height
1	Female	29	Left	Pain	Yes	35	40	10	30	1.48
2	Female	32	Right	Pain	No	80	70	6	20	1.54

Abbreviation: VAS, Visual Analogue Scale.

Table 2 Final follow-up

Patient	Final VAS	Final wrist flexion	Final wrist extension	Final grip jamar (pounds)	Final carpal height	Follow-up
1	0	50	60	45	1.42	12 mo
2	4	65	60	60	1.51	20 mo

Abbreviation: VAS, Visual Analogue Scale.

anatomic preserving techniques include pedicled vascularized bone grafts, autogenous bone grafting, and free vascularized bone grafts.[1,4] These techniques are indicated in patients with early stages of AVN of the capitate without arthritis, fragmentation, or carpal collapse.

In the two cases we treated, a vascularized bone graft from the dorsal radius 4th and 5th ECA was used. The benefits of this graft are: (1) the bone graft can be harvested through the same dorsal approach, (2) long enough pedicle to reach the capitate, (3) a bone graft of large enough size can be harvested from the distal radius without worrying about fractures as in smaller bones like the metacarpals, (4) no need of microsurgical anastomosis, and (5) pedicle found in a consistent basis on the dorsal aspect of the radius. Other vascularized pedicled bone grafts described in the literature to treat capitate AVN include the 2–3 intercompartmental supraretinacular artery[5] and a pedicled vascularized bone graft from the second metacarpal.[16] At the end, this procedure does not burn any bridges and still allows for salvage procedures in the future.

Arthroscopic partial capitate resection and interposition of palmaris longus graft are options that have been described for cases with carpal collapse and cartilage damage with variable results.[17] Vascularized osteochondral and bone grafts from the medial femoral condyle of the knee have been reported to treat capitate AVN.[18,19] Pyrocarbon capitate implants initially designed to replace the trapezium and specifically designed for capitate resurfacing have also been described to treat this condition.[20] Few cases have been described using this implant with encouraging results but with short follow-up. The most reliable treatments in these cases with progressive lunocapitate osteoarthritis are partial fusions of the wrist (four corner, capitolunate, capitohamate, scapholunocapitate).[2,4,7]

Limitations

Capitate AVN is a rare condition, and the treatment will depend on the cartilage status of the capitate and carpal height. We acknowledge the limitation of the cases presented due to the lack of long-term results. Longer follow-up studies are required to have better consensus on the treatment of these cases. Patients with preserved proximal articular cartilage of the capitate and carpal height, a 4th–5th ECA vascularized bone graft from the distal radius is a valuable option to treat this condition. If progressive osteoarthritis develops wrist, fusion is required.

Ethical Approval

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Written consent was obtained from the patients for their anonymized information to be published in this article.

Funding

None.

Conflict of Interest

None declared.

References

1 Hattori Y, Doi K, Sakamoto S, Yukata K, Shafi M, Akhundov K. Vascularized pedicled bone graft for avascular necrosis of the capitate: case report. J Hand Surg Am 2009;34(07):1303–1307
2 Peters SJ, Degreef I, De Smet L. Avascular necrosis of the capitate: report of six cases and review of the literature. J Hand Surg Eur Vol 2015;40(05):520–525
3 Tashjian RZ, Patel A, Akelman E, Weiss APPC. Avascular necrosis of the wrist and hand excluding the scaphoid and lunate. J Am Soc Surg Hand 2004;4(02):109–116
4 Murakami H, Nishida J, Ehara S, Furumachi K, Shimamura T. Revascularization of avascular necrosis of the capitate bone. AJR Am J Roentgenol 2002;179(03):664–666
5 Imai S, Uenaka K, Matsusue Y. Idiopathic necrosis of the capitate treated by vascularized bone graft based on the 2, 3 intercompartmental supraretinacular artery. J Hand Surg Eur Vol 2014;39 (03):322–323
6 Ferrand M, Bellemere P. Pyrocarbon interposition after capitate head resection. J Wrist Surg 2013;2(04):351–354
7 Whiting J, Rotman MB. Scaphocapitolunate arthrodesis for idiopathic avascular necrosis of the capitate: a case report. J Hand Surg Am 2002;27(04):692–696
8 Athlani L, Granero J, Dap F, Dautel G. Avascular necrosis of the capitate: case series of five patients and review of literature. J Hand Surg Eur Vol 2019;44(07):702–707
9 Nattrass GR, King GJW, McMurtry RY, Brant RF. An alternative method for determination of the carpal height ratio. J Bone Joint Surg Am 1994;76(01):88–94
10 Milliez PY, Kinh Kha H, Allieu Y, Thomine JM. Idiopathic aseptic osteonecrosis of the capitate bone. Literature review apropos of 3 new cases [in French]. Int Orthop 1991;15(02):85–94
11 Butterworth JA, Moran SL. The management of avascular necrosis in the carpus: Preiser's disease and avascular necrosis of the capitate. In: Slutsky DJ, ed. Principles and Practice of Wrist Surgery. Philadelphia, PA: Saunders; 2009:579–588
12 Niesten JA, Verhaar JAN. Idiopathic avascular necrosis of the capitate–a case report and a review of the literature. Hand Surg 2002;7(01):159–161
13 Vander Grend R, Dell PC, Glowczewskie F, Leslie B, Ruby LK. Intraosseous blood supply of the capitate and its correlation with aseptic necrosis. J Hand Surg Am 1984;9(05):677–683
14 Kadar A, Morsy M, Sur YJ, Laungani AT, Akdag O, Moran SL. The vascular anatomy of the capitate: new discoveries using micro-computed tomography imaging. J Hand Surg Am 2017;42(02):78–86
15 Ye BJ, Kim JI, Lee HJ, Jung KY. A case of avascular necrosis of the capitate bone in a pallet car driver. J Occup Health 2009;51(05):451–453
16 Usami S, Kawahara S, Inami K. Vascularized second metacarpal bone graft for the treatment of idiopathic osteonecrosis of the capitate. Hand (N Y) 2019;15(01):NP22–NP25
17 Shimizu T, Omokawa S, del Piñal F, Shigematsu K, Moritomo H, Tanaka Y. Arthroscopic partial capitate resection for type ia avascular necrosis: a short-term outcome analysis. J Hand Surg Am 2015;40(12):2393–2400
18 Higgins JP, Bürger HK. Osteochondral flaps from the distal femur: expanding applications, harvest sites, and indications. J Reconstr Microsurg 2014;30(07):483–490
19 Kazmers NH, Rozell JC, Rumball KM, Kozin SH, Zlotolow DA, Levin LS. Medial femoral condyle microvascular bone transfer as a treatment for capitate avascular necrosis: surgical technique and case report. J Hand Surg Am 2017;42(10):841.e1–841.e6
20 Jagodzinski NA, Taylor CF, Al-Shawi AK. Pyrocarbon interposition arthroplasty for proximal capitate avascular necrosis. Hand (N Y) 2015;10(02):239–242

